Construction of Container Terminal 4  
Port of Bremerhaven, Germany

Birgitt Brinkmann  
Universität Lüneburg, Fachbereich Bauingenieurwesen, Sudenburg  
brinkmann@uni-lueneburg.de

Stefan Woltering  
bremenports consult GmbH, Bremerhaven  
Stefan.Woltering@BremenPORTS.de

Abstract

All the expert forecasts predict that container throughput will double over the next ten years. If Bremerhaven – a seaport in the north of Germany – wishes to keep pace with these developments, the port facilities have to grow.

In order to provide the urgently required space, bremenports had already extended the quay by 340 m a few years ago. Construction phase Container Terminal (CT) 3a, however, was just the prelude to the much more difficult project Container Terminal 4, which will create four new berths for mega container vessels.

The terminal construction project will extend the riverside quay by 1681 m to a total usable length of 4720 m - the longest riverside quay in the world.

1 Introduction

Bremerhaven was founded in 1827 at the mouth of the river Weser to provide a new port for the Hanseatic City of Bremen, which lies approx. 70 km upstream (Figure 1). Today, Bremerhaven has become one of the most important maritime cargo handling centres in Europe. In 2006, the throughput of its automobile and container terminals will exceed 1.6 Mill. CEU (Car Equivalent Unit) and 4 Mill. TEU. Figure 2 shows an aerial view of the city and port of Bremerhaven.
After the first container arrived in Bremen on the 6th of May 1966 with the vessel “Fairland”, the container handling took place at different locations within the port of Bremen and Bremerhaven respectively. To provide a reliable long-term base for handling the growing container transport sector, Bremen’s municipal port authority decided in the late sixties to build a new quay on the Weser, the so called "Stromkaje" – the riverside quay.

Construction of the quay on the riverside started in 1970. In four stages (1, 2, 3 and 3a), 10 berths for container vessels were built and the quay grew to a length of 3,192 m (Figure 3), the world’s longest quay wall.
All the expert forecasts predict that container throughput will double over the next ten years (Figure 4). In order to provide the urgently required space, the City of Bremen (owner of the terminals in Bremerhaven) is again expanding its port on the mouth of the Weser. The construction of Container Terminal 4 (CT 4) started in 2004 and is scheduled for completion by spring 2008. It will provide four more berths for mega carriers.
2 Container Terminal 4

2-1 The Project

Container Terminal 4 will extend the riverside quay towards the north by 1,681 m to a total usable length of 4,720 m. The first 537 m are a direct extension of the Stromkaje. Beyond this, the new quay turns off to the north-west at an angle of 10 °, following the course of the Weser fairway. The terminal has a hinterland depth of 570 m, which means that the total port area will grow by roughly 90 ha.

The new terminal structure is located in tidal mudflats and extends onto the dyke foreland only in the south (Figure 5). In the north, the site touches the boundary to Lower Saxony. As the riverside quay replaces the dyke, the structure has to satisfy particularly stringent demands.

The construction of CT 4 includes the following works (Figure 6):

- rerouting the watercourse of Weddewader Tief
- replacing the unstable subsoil for the quay
- installing sheet piling on the waterside
- backfilling the quay and pile driving on shore
- concrete, steel and ancillary work
- infilling the hinterland
- building new dykes

Figure 5 Expansion area of CT 4 [bremenports]
2-2 Rerouting Weddewarder Tief

The CT 4 construction site is crossed by the Weddewarder Tief, which carries rainwater from parts of the city of Bremerhaven and the surrounding area in the north into the Weser (Figures 5 and 6). In order to create one coherent terminal area, the outfall has to be rerouted around the new terminal facilities in the east, and will subsequently flow into the Weser to the north of the new terminal.

![Diagram of the layout of CT 4][1]

Figure 6 Layout of CT 4 [bremenports]

2-3 Replacing the Unstable Subsoil

The container terminal projects on the mouth of the Weser have repeatedly encountered problems with difficult soil conditions (Figure 7). Down to a depth of 16 m below mean sea level, the planning engineers had to cope with unstable alluvial deposits, generally known as marsh soil. These deposits consist of alternate layers of sand and mud. The depth of the sand layers varies between a few millimetres and one metre. Although the foundation has better bearing capacity, it is by no means homogeneous. It consists of coarse sand, gravel, rubble, glacial loam, clay, silt and silty fine sand.

To enable the construction of the quay and the subsequent working areas, the unstable soil had to be replaced over a width of 60 m and a length of approx. 1,100 m, which means along roughly two thirds of the quay length. A total of 400,000 m³ of unstable marsh soil was excavated and replaced by sand with better bearing capacity. The marsh soil was dumped in the Outer Weser. The sand was taken from the Weser navigation channel by a hopper dredger and distributed in the foundation pit.
Another problem was the siltation. The brackish water at the mouth of the Weser contains large quantities of fine sediments which can cause deposits of up to three metres a year in port areas with reduced currents. Especially during the soil replacement phase considerable effort was undertaken to prevent the sediments from settling. This was done by a special water injection dredger which whirls up the sediment and keeps it suspended.

2-4 Sheet Piling

Construction of the new quay is based on the principle of an anchored wall, backed by a load-retaining slab (Figure 8) - a design with good experience obtained from earlier projects.

The main bearing element of the new quay consists of heavy-duty combined sheet piling, made up of double piles and intermediate piles. The double piles are between 36 and 40 m long, they weight up to 25 t and were driven into the subsoil at intervals of approx. 2.35 m. Intermediate piles fill in the gaps between the bearing piles.

The sheet piling is anchored by batter piles, which are also placed at intervals of 2.35 m. Each of these 45 m long piles bears a load of around 180 t.

As it is not possible to fill in an area with sand to create a suitable working basis beside the Weser fairway, jack-up platforms were used to drive in the piles. These platforms stood on the underwater slope of the soil replacement pit (Figure 9).
Once the wall has been anchored, the area behind the sheet piling has been filled in with sand up to a level of 2.50 m above mean sea level and CT 4 became a land construction site. The three rows of 22 and 32 m long Peine steel piles, set in the lengthwise direction of the quay, are driven into the subsoil from this new generated land.
2-5 Concrete, Steel and Ancillary Work

The reinforced concrete slab (pier slab, s. Figure 8) with the integrated wave absorber is also produced on the filled in sand area using cast-in-place concrete. The pier slab is 80 cm thick and 20 m wide, and is produced in stages of approx. 50 m.

Pier slab with wave absorber and crane runway are produced as a monolithic structure over the entire length of approx. 1.7 km. This is possible thanks to a special low-heat concrete mix formula, intensive curing and reinforcement which ensure even distribution of cracks. This monolithic construction principle has already proved successful in previous terminal construction projects in Bremerhaven.

The wave absorber principle was already used when the first stages of the quay were built at Bremerhaven during the 1970s and again proved its effectiveness of absorbing waves and preventing water overtopping the quay during pilot tests in 1997. The wave absorber effectively protects the quay and terminal in case of extremely high incoming storm tides.

After the 80 cm thick ceiling of the wave chamber has been concreted, the quay structure, with a height of 7.50 m above mean sea level, forms the line of the dyke and offers the necessary protection against floods.

The approx. 30.48 m (100 feet) span for the gantry cranes requires a landside runway with a separate bearing structure behind the quay itself (with deep foundations of cast-in-place driven piles, Franki System).

The plans also envisage permanently lowering the groundwater to such an extent that any excess water pressure can be absorbed, even in case of extremely low outgoing tides.

To keep the noise within acceptable limits modern vibration technology was used to insert the piles. Only along the last few metres are the individual piles subsequently driven into place to guarantee sufficient load bearing capacity.

The corrosion of bare steel parts in the brackish water area at the mouth of the Weser poses a permanent problem. In the tidal area, pitting can amount to up to one millimetre per annum. All steel parts beside the water have to be given passive and active corrosion protection. Passive corrosion protection takes the form of four coats of polyurethane-based anticorrosive paint, which is applied from the top of the quay down to the bottom of the mooring basin. There is also a cathodic protection system, powered by an external current source.

The new quay will be equipped with all the usual features, such as double bollards, each designed to withstand 2,000 t of tension. The fendering consists of reinforced concrete fender slabs, suspended from steel piles in front of the quay. The 3.40 m long foam-filled floating fenders are two metres in diameter.

The surface will be given a bituminous base course. Rainwater falling onto this area will be collected in slotted channel drains and run off via gullies. From there it flows through storm sewers into a central collection sewer, from where it is carried through the quay area and then runs off into the Weser.
2-6 Infilling the Hinterland and Construction of New Dykes

About 10.5 Mill. m³ of sand have to be distributed over the Container Terminal 4 construction site. Some of that quantity is extracted from the Outer Weser fairway using hopper dredgers (maintenance work). The rest will be taken from the River Jade or from another sand extraction site, roughly 20,000 m³ are extracted every day.

Figure 10 shows the sheet pile driving and the simultaneously executed backfilling.

![Figure 10 Ongoing construction works](bremenports)

Dredgers will also excavate new mooring basins in front of the quay to ensure sufficient navigable water depth for the ships at all times.

To protect the hinterland of the terminal against the vagaries of the North sea, new dykes will be built in the north and east of the terminal extension with a crest height of 8.50 m above mean sea level. The dykes consist of sand and a two metre thick covering layer of clay.

The first berth, with a length of 330 m, is to go into operation in October 2006. The second (330 m) will follow in January 2007, the third (510 m) in August 2007. The fourth and final berth (510 m) will be handed over in April 2008.

2-7 CT 4 at a Glance
3 Environmental Issues

3-1 General Requirements

The construction and operation of CT 4 influence the environment, affecting many different areas. The authority responsible for design and location approval, the North-West Directorate of Waterways and Shipping (WSD) in Aurich, held a scoping meeting with a panel of experts to ensure the investigation of all possible consequences of the project for humans, flora and fauna.

The responsible bremenports engineers are thoroughly familiar with the required environmental impact assessment, which involves examining, describing and evaluating the anticipated effects of terminal construction and operation. If negative environmental impact cannot be avoided, it has to be reduced or compensated for in accordance with the German law on Environmental Impact Assessments.

As soon as construction work begins, the machinery generates noise and the pollutants emitted by the vehicles on the building site already impinge on the surrounding area.

Once operation has begun, the neighbouring residential areas will also be affected by the noise and light emanating from the terminal. In addition, there will be airborne pollutants, for instance as a result of container handling. And finally, the face of the environment will also change – with containers and cranes where there used to be mudflats.

These and other effects on the environment play a central role for the work of the port planning engineers. From a very early stage, they have to consider whether negative impact can be avoided (e.g. by reducing the noise level of technical equipment) or, if not, how it can be compensated for. Failure to come up with acceptable compensation solutions could jeopardise planning permission for a construction project such as CT 4.

Length of the former container quay: 3,237 m
Length of the new quay wall: 1,681 m
New terminal operating area: approx. 90 ha
Number of new berths: 4
Capacity of full potential: more than 6 million TEU
Completion of first berth: October 2006
Completion of all work: April 2008
Construction and planning costs: approx. 500 Million Euros
3-2 Creating Habits

As the port expands, valuable natural areas are lost. The environment loses tidal habitats, with wet and sandy areas, as well as the brackwater zone with its tidal mudflats, salt meadows and brackish reed beds. Accordingly, ecological compensation has to be made elsewhere.

The statutory regulations demand comprehensive compensation. Former farmland is to be turned into ecologically valuable zones. Two locations have been selected for this task: Grosse Luneplate to the south of Bremerhaven, and an area on the Wursten coastline north of the city (Figure 11).

The central substitute site for CT 4 will be on Luneplate. The land behind the dyke is to be flooded in the endless circle of turning tides – but carefully controlled, to ensure that the residential areas in the neighbouring marshland remain safe (Figure 12).

A new flood barrier will be built on the Weser especially for that purpose, to protect the hinterland from storm tides. The new eco-landscape, criss-crossed with artificial tidal channels and bordered by a dam, will be largely left to its own devices once the workmen and excavators have left the scene.

At the Wursten coast, bremenports plans to open the lower summer dyke so that the area between the summer dyke and the main dyke can be flooded by the high tides of the North Sea – a crucial factor for upgrading the ecological rating of this area on the outskirts of the Lower Saxony Mudflats national park.

Figure 11  Locations of the compensation areas [bremenports]
Figure 12  Planned compensation measurements at Luneplate [bremenports]

4 References

Project information by courtesy of
- bremenports GmbH & Co KG (principal)
- HOCHTIEF AG (contractor)

ISL. Institute für Seeverkehrswirtschaft und Logistik (Institute of Shipping Economics), Bremen, 2004.